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ELECTRICAL DISCHARGE APPARATUS FOR FORMING

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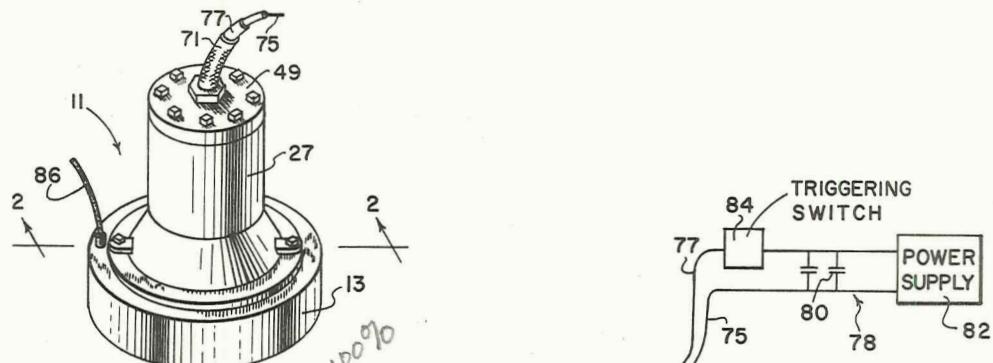


FIG. 1

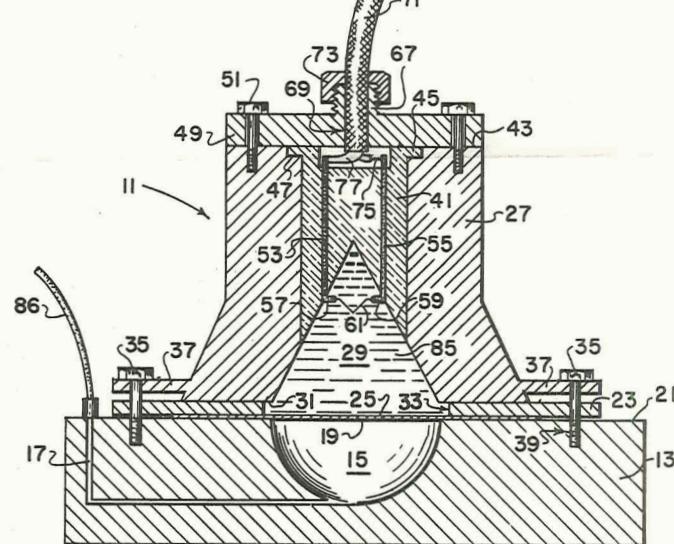


FIG. 2

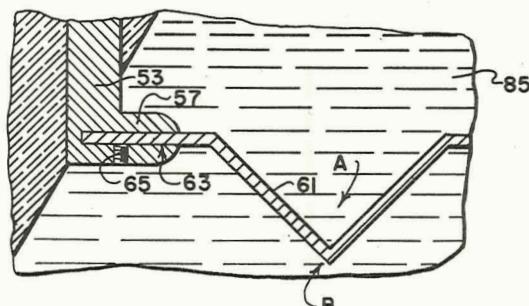


FIG. 3

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**ELECTRICAL DISCHARGE APPARATUS
 FOR FORMING**

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2 Claims. (Cl. 72—56)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to high energy rate forming and more particularly to an electrical discharge apparatus for high energy rate forming.

Recent trends in manufacturing for formed metal parts in large sizes and formed metal parts having complex configurations have led to the development of high energy rate forming techniques which provide an instantaneous force for forming which would be impractical by conventional machinery such as the hydraulic forging press and drop hammer. These high energy rate forming techniques generally involve the use of chemical compounds which are exploded under water whereby shock waves are generated and transmitted by the water against a metal blank. Chemical explosives do not, however, provide for rapid and uniform repeatability and are often hazardous to handle and store.

The explosivelike energy release of a rapid discharge of electrostatically stored energy between two electrodes has also been satisfactorily utilized to a limited extent for high energy rate forming. The placing of a high electrical potential of several kilovolts between two electrodes located under water results in a current flow which first vaporizes the water in the vicinity of the electrodes and then causes the vapor to become highly dissociated and ionized. This ionized vapor is a highly conductive path and permits a tremendous electrical current discharge between the two electrodes with a corresponding intense pressure or shock wave that radiates radially from the conductive path and is transmitted by the water. However, a considerable amount of current is necessary before the ionized vapor is formed which means less useful work and somewhat unpredictable results from one electrical discharge to another. Also, the explosive path of the electrical discharge could not be shaped to obtain the versatility of chemical explosive charges which by having a cylinder, cord, or sheet shape could obtain an energy release pattern which would tend to apply a forming force exactly where needed.

Accordingly, it is an object of this invention to provide a highly efficient electrical discharge apparatus which rapidly and repeatedly obtains energy releases in a particular direction.

A further object is to provide an electrical discharge apparatus which will release and control sufficient energy to efficiently form materials.

Other and further objects, uses, and advantages of the present invention will become apparent as the description proceeds.

In accordance with this invention an electrical discharge apparatus is constructed having a blast head with a cone-shaped chamber and a die block in cooperative relationship thereto which has a forming cavity aligned with the chamber. A metal blank which is adapted to be formed separates the chamber from the forming cavity.

Within the chamber and adjacent the apex thereof are two spaced electrodes having a metal wire bridged there-

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between which has a V-shaped portion converging away from the apex of the blast chamber. Also, within the blast chamber is a pressure transmitting liquid.

The two electrodes are electrically connected to a condenser bank through a suitable triggering switch. When the condenser bank is discharged through the electrodes and wire, the wire explodes and generates a shock wave which is transmitted by the liquid toward the blank. The electrical circuit and wire parameters are selected whereby a current pause or "dunkelpause" does not occur.

This will be more readily understood by the following detailed description when taken together with the accompanying drawings, in which:

FIGURE 1 is a perspective view of an apparatus for electrical discharge forming.

FIGURE 2 is an elevation cross-sectional view taken along line 2—2 of FIGURE 1, showing some parts in full, and including an electrical schematic wiring diagram.

FIGURE 3 is a partial elevation cross-sectional view showing the electrode and wire relationship for the apparatus of FIGURE 1.

Referring now to the drawings, there is shown in FIGURES 1 and 2 an apparatus 11 for electrical discharge forming having a die block 13 with a forming cavity 15 and a bore 17 communicating with the cavity 15. A metal blank 19 rests upon the upper surface 21 of the die block 13 and covers the forming cavity 15. The blank 19 has a hold-down ring 23 upon its upper surface 25 to frictionally hold it in position. A blast head 27 with an inner cone-shaped chamber 29 converging from an opening in its base surface 31 is situated upon the upper annular surface of the hold-down ring 23. The forming cavity 15 of the die block 13, the aperture 33 of the hold-down ring 23, and the conical chamber 29 of the blast head 27 are in an aligned relationship. As shown best in FIGURE 2, cap screws 35 extend through lugs 37 integral with the blast head 27 and on through the hold-down ring 23 near its outer periphery, and into threaded bores 39 within the die block 13.

The blast head 27 has a dielectric material portion 41 which forms the region adjacent the apex of the chamber 29 and extends to the upper surface 43 of the blast head 27. The dielectric material portion 41 has a peripheral flange 45 resting upon an annular shoulder 47 of the blast head 27 to prevent it from slipping down into the chamber 29. A pressure plate 49 is secured by a series of cap screws 51 to the upper surface 43 of the head 27 to prevent the dielectric material portion 41 from being blown out by an electrical discharge within the chamber 29 as described hereinafter.

Extending through the dielectric material portion 41 are two spaced electrodes 53 and 55 having inner bent portions 57 and 59, respectively, directed in an opposed manner into the chamber 29 adjacent its apex. A metal wire 61 having a centrally located V-shaped portion is fixed by its opposite ends to the opposed bent portions 57 and 59 of the electrodes 53 and 55, respectively. This is accomplished as shown in FIGURE 3 by placing each end of the wire 61 into a bore 63 provided within each of the bent portions 57 and 59 and securing it by a set screw 65. The wire 61 is positioned whereby its V-shaped portion converges in the diverging direction of the chamber 29 and points toward the metal blank 19.

The pressure plate 49 has a centrally located boss 67 upon its upper surface and an opening 69 which extends through the boss 67 and plate 49. A coaxial transmission line 71 extends through the opening 69 and is held therein by a collet chuck 73 which fits tightly about the line 71 and is in threaded contact with the boss 67.

The coaxial transmission line 71 is electrically connected to the electrodes 53 and 55 by attaching its core

conductor 75 to electrode 55 and its shield conductor 77 to the other electrode 53. The electrical conductors 75 and 77 are also attached to a high energy electrical storage bank 78, which is illustrated in FIGURE 2 as a series of parallel related capacitors 80 having a power supply 82 to charge them to their high electrical potential. A suitable triggering switch 84 is provided in the electrical conductor 77 for discharging at the proper moment the capacitors 80 through the electrodes 53 and 55 and wire 61 whereby the wire 61 will be vaporized with explosive violence.

The chamber 29 is filled with liquid 85, water for example, for transmitting the shock wave generated by the exploding wire 61 against the metal blank 19 so that it will be formed against the die cavity 15.

The metal blank 19, although tightly held between the die block 13 and the hold-down ring 23, is able to slip slightly when being forced into the forming cavity 15. This slight slippage prevents the blank 10 from rupturing when undergoing the forming operation.

As the exploding wire 61 within the chamber 29 will form the blank 19 against the cavity 15 faster than the air therein has time to leave through the bore 17, it is necessary to exhaust the air within the cavity 15 before the wire 61 explodes by attaching a vacuum line 86 to the bore 17. Otherwise, the air, after being compressed by the blank 19, would deform the blank.

A directional shock wave is generated by the exploding wire 61 because it is bent into a V-shape. This is believed to be due to the magnetic flux which normally surrounds an electrical current path and which tends to bring itself into a state of equilibrium. When the current path is bent, as would result in using the V-shaped wire 61, the magnetic flux in the acute angle region of the bent path, region A in FIGURE 3, would have a high density due to its concentration in a region of smaller dimensions, and, correspondingly, the magnetic flux in the obtuse angle region, region B in FIGURE 3, would have a low density due to its spreading out in a region of greater dimensions. Accordingly, a situation occurs in the region of the bent current path which results in a preferential motion of particles of matter away from the high density magnetic flux toward the low density magnetic flux in an effort to bring about a state of equilibrium. It is this preferential motion which is believed to result in the shaped shock wave generated by an electrical discharge through a V-shaped path being directed in the converging direction of that path.

The shock wave generated by exploding the wire 61 has substantially the same V-shape as the wire so that when the shock wave moves outwardly from the vaporized wire 61 its apex strikes against the middle region of the metal blank 19. This is advantageous because the forming of the middle portion of the metal blank 19 first will result in a more uniform wall thickness to the finished blank 19 and more efficient forming. Otherwise, if the apex of the shock wave front first came against the metal blank 19 adjacent its outer periphery and formed that portion against the cavity 15 and then started forming the middle portion, the blank 19 would have been prevented from slipping properly. Improper slipping of the metal blank 19 may cause a rupture, non-uniform wall thickness, and decrease in efficiency of the forming operation.

In addition, the cone-shaped configuration of the chamber 29 further shapes the explosive pressure or shock wave generated by the exploding of the wire 61. The conical shape of the chamber 29 represents the minimum volume condition for deforming a metal blank 29, and with the explosion occurring adjacent the apex of the chamber 29, the shock wave is driven toward the diverging direction of the chamber 29 without appreciable loss of energy. If, for example, the wire 61 exploded in an unconfined medium, only that portion of the resulting spherical energy distribution which would be use-

ful would be encompassed within the conical volume defined by the metal blank 19 and the wire 61. The rest of the energy distribution outside of this conical volume would have been lost from performing useful work.

For efficient operation, the parameters of the metal wire 61 and its electrical circuit should be selected by known criteria whereby a current pause or "dunkelpause" will not occur and whereby the capacitors 80 are completely discharged approximately instantaneously with the exploding of the wire 61. It is also preferred if the included angle of the V-shaped portion of the wire 61 has an angle between 50 and 70 degrees and the included cone angle of the chamber 29 has an angle of approximately 55 degrees.

It is apparent that an electrical discharge system utilizing a bent bridge wire has been disclosed which is instrumental in concentrating the explosive force of an electrical discharge and this system has been incorporated into an apparatus which takes full advantage of the directional sense of the electrical discharge by bringing the explosive force generated thereby against a metal blank with high efficiency.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced other than as specifically described.

What is claimed is:

1. In combination with a die having a forming cavity adapted to be covered by a restrained blank:

- (a) means for directing a shock wave having a substantially V-shaped front toward the center of said forming cavity whereby the point of said shock wave will strike the middle portion of said blank to form said blank from its center outwardly;
- (b) said means including:
 - (1) a blast head having an inner cone-shaped chamber converging from an opening in the peripheral surface thereof;
 - (2) said blast head joining said die with said opening being aligned with said cavity;
 - (3) two spaced electrodes supported by said blast head and extending into said chamber adjacent the apex thereof;
 - (4) a wire having a V-shaped portion substantially aligned with the center of said cavity and fixed to and extending between said electrodes, and
 - (5) said V-shaped portion converging away from said apex of said chamber.

2. In an apparatus for forming metal blanks:

- (a) a blast head having a base surface adapted to rest upon the surface of a die block having a forming cavity;
- (b) said blast head having an inner cone-shaped chamber converging from an opening in said base surface, said opening adapted to be aligned with the forming cavity of said die block;
- (c) two spaced electrodes supported by said blast head and extending into said chamber adjacent the apex thereof;
- (d) a wire having a V-shaped portion;
- (e) said wire being fixed to and extending between said electrodes and having its V-shaped portion converging in the diverging direction of said chamber and pointing toward the center of the opening in said blast head;
- (f) said wire being adapted to vaporize with explosive violence upon the placing of a high electrical potential between said electrodes so as to cause a shock wave having a V-shaped front diverging toward the opening in said blast head and pointing toward the center of the opening in said blast head whereby a metal blank adapted to be placed over the forming

cavity of the die block will be formed from its center outwardly;

(g) said cone-shaped chamber of said blast head being adapted to drive the shock wave toward the opening of said blast head without appreciable loss of energy; 5 and

(h) means including a switch for supplying a high electrical potential to said electrodes so as to cause said wire to explode at a desired instant;

(i) said means and said wire having parameters selected whereby a current pause or "dunkelpause" does not occur.

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10 WILLIAM J. STEPHENSON, *Primary Examiner.*NEDWIN BERGER, *Examiner.*